



OUR CANALS.

OF THE SUBJECT OF THE

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AND

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KEEFER,

OF CIVIL ENGINEERS.

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OUR CANALS.

LETTERS ADDRESSED TO THE EDITOR OF THE "MAIL"

ON THE SUBJECT OF THE

BAIE VERTE

AND

WELLAND CANALS,

BY

SAMUEL KEEFER,

MEMBER OF THE INSTITUTION OF CIVIL ENGINEERS.

1874.

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INTRODUCTION.

The following letters on OUR CANALS appeared at different times during the last year in THE MAIL, and are now collected and reprinted in pamphlet form for convenience of reference.

They relate to works of political and commercial importance to the Dominion, and were written in reply to certain official criticisms found in the blue book on the reports which the writer, in conjunction with other engineers had, by request of the Government, laid before them.

In the course of this reply it has become necessary to shew wherein the works which have been projected by the Department of Public Works do not conform to the best modes of construction, and will consequently fail to afford the facilities, or to attain the success which the people of this country have a right to expect from the large outlay so freely devoted to them.

The purpose of these letters is to prove that as regards the Baie Verte Canal, the only practicable mode of opening a navigable channel through the Isthmus is the one in which the tidal scour is employed to form and maintain it; and as regards the Welland Canal, it is shewn that the enlargement when completed according to the official plans, will be defective in some of its most essential features.

In this progressive age, when improvements are being made in every branch of the engineering profession, when great and powerful lines of railway are brought into more direct competition with the inland navigations—and when the West is anxiously looking for the cheapest outlet to the sea, it becomes essential to the success of our canals that the works should be planned and executed according to the best examples of modern practice.

SACKVILLE ST., PICCADILLY,
LONDON, JAN'Y, 21 1875. }

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OUR CANALS.

I.

To the Editor of The Mail.

SIR,—The *Globe* having called public attention to Mr. Page's report on the proposed Baie Verte Canal, and having also referred to my report on the same subject, I beg you will favour me with space in your paper for a few short letters, in which I propose to refer, as briefly as possible, first, to the Baie Verte Canal, and afterwards to the works recently placed under contract on the Welland.

As regards the first, it is a matter of serious public concern if this Dominion has in any way been pledged to Mr. Page's report; for not only is the cost of such a canal as he commends out of all proportion to its utility, but it is doubtful if it is possible to make or maintain a navigation on the line and in the manner suggested by him.

It cannot be denied that the Chief Engineer of the Department of Public Works has enjoyed peculiar advantages for maturing his plan for this canal. It is now five years since his attention was first officially directed to this subject, and he has been permitted to have elaborate surveys made under his own directions, the results of which were placed before him by his assistants in April, 1872. The line then recommended was the Au Lac and Tidnish, crossing the Cumberland Ridge. No estimate of cost was given, but some idea of the magnitude of the undertaking could be formed from the quantity of work estimated as necessary for the construction of a canal on the scale recommended by the Canal Commission, accessible for vessels of fifteen feet draught at low water, at both entrances—that is, for a whole tide canal. On the quantities thus given, the cost was variously estimated at from twelve to fifteen millions of dollars. It was at once evident, that the object of opening such a communication through the Isthmus was not of sufficient importance to warrant the Government in embarking in such an enormous expenditure.

The Chief Engineer was expected to prepare a report for the Parliament then in session, but pleading other engagements, he declined entering upon the duty at that time. The Minister of Public Works then requested Mr. Gzowski and myself to report on these plans and documents. Having first made a personal examination of the locality, I submitted a preliminary report in August, 1872, pointing out the very grave objections to the Au Lac and Tidnish line, and suggesting another line from Laplanche to Tidnish and Weeks' Head.

In this report, approved by Mr. Gzowski, we gave it as our opinion that a half-tide canal, of the dimensions recommended by the Canal Commission, and sufficient for all practical purposes, could be constructed at a cost of between five and six millions of dollars. I was then requested to make a location survey of the proposed line, to submit plans and prepare for placing the work under contract. This duty was care-

fully performed with all expedition, and my general report was sent in in February, 1878, with a detailed estimate, showing, as we had before stated, that the canal on my line could be constructed for five millions of dollars.

My line, however, did not meet the views of certain influential parties in New Brunswick—the Province which had always taken the greatest interest in the proposed canal. The Missiquash River is the boundary line between New Brunswick and Nova Scotia, and it so happened that the line which I considered most eligible, and best for the interest of the Dominion, fell wholly within the Province of Nova Scotia.

From what I have since learned, I am convinced that if I could have reconciled it to my loyalty to Canada to make the Bay of Fundy terminus at or near Au Lac instead of Laplanche, all local opposition to my line would cease.

In May, 1872, Parliament being then in session, the Government deemed it expedient, owing to the diversity of opinion that existed in regard to the different projects submitted, more particularly the half-tide project, to refer the whole matter with all the documents to the Chief Engineer for report.

In the performance of this duty, Mr. Page at length found it necessary to make a personal examination of the locality, and to have other surveys made, particularly for the purpose of finding "the lowest point of the water-shed"—matters which it would have been more professional to have carefully considered and attended to at the outset.

In December last he submitted his report recommending the Au Lac and Tidnish line by the valley of the Missiquash, and on the plan of the isthmus attached to his report, he calls it the "final location."

The estimated cost of a half tide canal is \$7,700,000. For a three quarter tide canal \$8,000,000, and for a whole tide canal \$8,500,000.

It will be observed that Mr. Page does not offer any opinion as to which of these plans it is desirable to adopt; neither does he give any idea of the extent of the traffic to warrant this large expenditure.

It must also be understood that this is not the Au Lac and Tidnish line of the first survey, which followed up the Au Lac, and crossed the Cumberland ridge, the line to which I so strongly objected in my first report; nor yet is it precisely the Missiquash line of the first survey, but a great improvement on both. Still it is open to the insurmountable objections which I intend to refer to in my next letter.

BROCKVILLE, 1st. May, 1874.

II.

In my first letter I gave a brief statement of the efforts made by our Government since confederation to revive and bring to a practical issue a project which has been agitated for the last fifty years for a canal through the neck of land uniting Nova Scotia and New Brunswick, and connecting the Bay of Fundy with the Gulf of the St. Lawrence.

The so-called Baie Verte Canal would shorten the sailing distance between Quebec and St. John, and other ports on the Bay of Fundy and the Basin of Minas five hundred miles, and would save the delay and risk attending a voyage around the Atlantic Coast of Nova Scotia.

In the comparatively isolated condition of the Provinces before confederation the necessity for this short line of communication was not felt; but now that they form one united Dominion, bound together by ties political and commercial, the trade growing up between them must tend year by year to give greater importance to the proposed shorter and safer line of navigation.

The results of the surveys, so far, only serve to confirm the opinion entertained by all parties, that the construction of a canal adequate to the wants of the trade, will be a work of no ordinary magnitude. It is well, therefore, that the formidable difficulties to be encountered, the line to be selected, and the plans suggested for adoption, should receive mature consideration before embarking in the expenditure.

I now propose to point out the insuperable objections to Mr. Page's "final location" for this canal, the Au Lac and Tidnish by the valley of the Missiquash.

1.—THE WESTERN ENTRANCE.

Notwithstanding the very strong objections urged against this entrance in my general report, Mr. Page still proposes to carry out "the original idea," and to establish the Bay of Fundy terminus on the lee shore in Cumberland Basin, a little to the east of the mouth of Au Lac, where the prevailing south-west wind blows directly into the funnel-shaped bay, and the rise of tide varies from thirty-eight to forty-eight feet. It is difficult to conceive of a more dangerous entrance to a canal.

It was stated in my report that "a terminus at Au Lac, as represented in the Departmental chart, would expose the lock-gates to the direct assault of the sea, and the full force of the south-west winds; the heaviest that beat upon this shore. In such a position it would be impossible to maintain the lock-gates, and the difficulty for vessels making or leaving the entrance would be serious. * * *

"In proof of the statement that the south-west winds act with more force at Au Lac than at Laplanche it is only necessary to refer to the character and condition of the dykes at each place. At Laplanche they are of simple construction and easily maintained, while at Au Lac they are of stronger build and protected from the sea by close piling outside, at a very considerable expense—so great indeed that since the occurrence of the Saxby tide in 1869 many hundreds of acres of valuable marsh lands have been abandoned, it being too costly to restore the dykes."

To meet these objections, Mr. Page has modified "the original idea" by placing the entrance locks a short way inland, not in the direct line of the piers as at first intended, but in a line inclined to that of the piers. He also changes the direction of the piers to give better protection to the entrance, and places them where "the volume of water at the rising tide is divided into two parts, one taking a north-east direction up the River Tantamar, and the other a southerly course towards Sharp's Creek."

Having made these changes in the position of the piers and locks, he dismisses all apprehension of the dangers referred to by the following remarks: "But as the line would be nearly east, and the range of the lock-gates north-east, it will be evident that the circumstances are not as represented in the above quotation, apart from the result certain to be produced by the alternate meeting and separation of the waters of the two channels."

This paragraph is not very clear. But it is supposed to mean that in consequence of the curve at the junction of the piers and canal, the lock-gates will be protected from the action of the waves, and that as the terminus is in an eddy between two currents, it is quite safe.

That this is not a sufficient answer to the objections raised must be evident from the following considerations. Speaking of the meeting of the currents, he remarks that: "the points of convergence as well as those of divergence are constantly changing with the rise and fall of the tides; nevertheless there is invariably an eddy, or large area of comparatively smooth water."

It is obvious that the shifting nature of the currents, as here described, between the

Scylla and *Charybdis* of the proposed entrance, must render it impossible for vessels to make it with any degree of certainty. They may be thrown upon the piers, or, failing to enter between them, may fall into either of the adverse currents.

Again, referring to that part of the canal leading from the piers inward to the first lock, it is observed that "the sides of this part of the channel are to be protected by a docking of timber well tied into the banks, or by a mass of rubble masonry." No doubt this is a very necessary precaution against the surge from the entering waves; but, taken in connection with the fact that the channel between the piers is larger than that within the canal, there is every reason to fear that the waves from the bay will be a source of imminent danger to the lock-gates.

The special arrangement and vast expense proposed for the protection of the entrance in such an exposed position, and for such an enormous range of tide, show that the Chief Engineer appreciates, to a certain extent, the difficulties and dangers of the position; but it is extremely doubtful if he will be able to maintain the lock-gates and the other works forming the entrance. In my judgment this is a very grave question for our Government to consider. Mr. Page has not fairly met the difficulties I have stated, for if they are carefully weighed, it must be obvious that he was not warranted in speaking so confidently as he has done of the entire safety of the western entrance.

2.—THE EASTERN ENTRANCE.

In comparing the present plan for this entrance with the original, a most material difference is observed. Instead of two parallel piers running out 9,200 feet into the Bay, we find the two piers now so placed as to inclose a triangular basin of about eleven acres in extent, and that they have been reduced to 4,000 feet in length. It is not proposed, however, to dredge out the whole of the enclosed basin, but only a channel of 200 feet in width alongside the north pier. This shortening of the piers is represented to be due to a correction made with regard to what may properly be considered the true level of low water, which on more careful enquiry is now found to be somewhere between sixteen and twenty-seven inches higher than shown by the chart. This is a most important correction, since the effect of it is to show that the distance from shore to low water entrance for vessels of fifteen feet draught is not half of what it was represented to be on the Departmental chart. I draw attention to it now more particularly as I shall have occasion to refer to it again when speaking of my own plan for the Baie Verte entrance.

Baie Verte is shut in and protected from westerly and northerly winds by the main land, and the point running down to Cape Tormentine, but it is completely open to easterly winds. It is a very shallow bay. In a limited tideway (of nine feet ranges) the shallows at its head dry out to a distance of three-quarters of a mile from shore. From fifteen feet at low water opposite Tidnish Head, it gradually shoals to this dry margin without any intervals of deeper pools.

In selecting a suitable point for forming an artificial harbour, it is desirable that it should not be too near the beginning of shoal water. There should be room and verge enough for a vessel to bring up should she, by any chance, miss the entrance when making it under an easterly wind. Mr. Page has placed the entrance to the harbour at or near this limit, or beginning of fifteen feet at low water, where in fact the hydrographic contour line of three fathoms at low water, would show the entrance to be in a *cul de sac*.

Having described the position and dangers of the two entrances, I intend, in my next, to show that the cutting of a canal between them on the line and in the manner proposed by Mr. Page is impracticable.

Brockville, May 5, 1874.

III.

In pronouncing Mr. Page's plan impracticable, I do not say it is impossible to cut a canal on the line, and in the manner suggested by him, but that the difficulties are so great, and the expense will so far exceed the advantages likely to be derived from the canal, in our day, either commercially or politically, that the Government would not be warranted in undertaking it.

My reasons for this statement are given under the following heads:

1—QUICKSAND.

The line of the canal must necessarily pass through a tract of country where it is more than probable that deposits of quicksand will be found. Indications of this material may be observed in the side ditches of the Intercolonial Railway, and in the channels of the four rivers which drain the Cumberland and Westmoreland marshes into Cumberland Basin. Borings along the several explored lines reveal the fact that at certain variable depths below the superficial bed of clay, and falling within the prism of the proposed canal, there is sand, quicksand, and sandstone rock; and on Mr. Page's first survey quicksand is marked on the sections of the Au Lac and Missiquash lines.

Engineers generally understand the difficulty of dealing with this substance. In my first report on the Au Lac and Tidnish line, it was stated that "the section on the line also shows a large amount of quicksand, a material still more difficult to deal with than solid rock itself, and rendering the operation of cutting a canal through it most uncertain." If quicksand can be drained and made dry, it can be as easily removed as any other kind of sand, but so long as it is saturated with water, it remains in a semifluid state, and no channel can be made through it.

Quicksand is defined by Mr. McAlpino to be "a mixture of fine sand with such a proportion of clay or loam as enables the mass to retain water within itself, and when in this condition, after it has been trampled upon for a short time, it begins to quake, so that it may be called quakesand. When it reaches this condition, if it is left quiescent for a few hours the heavier particles of sand and clay settle down and expel the water, and the mass becomes firm. If, on the other hand, it is further disturbed by the feet of the workmen, it becomes more and more fluid, additional material flows in from the sides, and no progress can be made with the excavation."

Seeing that attention was directed to this question in my first report on "the original" Au Lac and Tidnish line, now abandoned, and that part of this line was common with the Missiquash line, it was but reasonable to expect some reference to it in the general report of the Chief Engineer. From the manner in which the marsh lands around Cumberland Basin have been formed by the sea, quicksand may be unavoidable, and it seems improbable that so slight a change in the location of the Missiquash line, as now suggested, should render it entirely free from them. It would require a most minute examination by borings and test-pits, to be assured of the entire absence of this material. Mr. Page has made no reference to this subject in his report. His failure in supplying the necessary information on this important point has involved his whole scheme in doubt and uncertainty. He has apparently been so much occupied in criticising my plan that he has overlooked many important particulars connected with his own.

The Chief Engineer sees no advantage in making use of the tidal scour to aid in the removal of any part of the material as suggested in my general report. He is so

conservative in his practice as to prefer "the ordinary uninteresting manner of doing the work by manual labor or steam excavators, or both combined." Therefore if quicksands occur—as there is every probability they will—they are to be removed by dredging, or by manual labor. But it is evident from the foregoing that this will be enormously expensive, and almost, if not altogether impossible.

2—FLOATING BOGS AND FLUID MUCK.

At the sources of the Missiquash and Laplace are vast tracts of this material. The "final location" passes through it for miles. Its surface stands at an elevation varying from eleven to eighteen feet above the assumed low water surface of the canal; and as a varying level of three feet is provided for within the canal, it will still stand from eight to fifteen feet above its high water surface. It is a part of the plan to drain the marshes, but to what extent and in what manner is not described. The surface of these bogs has a varying level as well as the canal. They consist of "a species of live moss from ten to fifteen inches deep, under which is a stratum of one foot or more in depth of closely matted roots." This floats upon the fluid muck, the whole depth being from six to ten feet. In passing through this bog the canal banks, both sides, are to be made water-tight, so as to keep back the bog, and prevent it running into the canal. By what system of weirs and regulating gates the bog is to be kept back and only the water admitted into the canal is not stated. But it is clear that the canal must be isolated from the marsh lands, otherwise it will be subject to irruptions from the bog and muck, and if by any chance quicksand is found under the seat of the banks they cannot be maintained, and the attempt to form the canal in this manner must fail.

3—DRAINAGE.

It is not reasonable that the Dominion should be charged with the drainage of the marsh lands. In forming the canal it may be well to give facilities for improving the lands, provided in so doing the cost of the canal is not increased. It must be remembered that the main object is to open a canal, not to drain the marshes. By leaving them as they are the proprietors can improve them or not, as they think best.

As the proposed canal crosses the head-waters of the Missiquash, the drainage of the marsh lands must be received into the canal, and along with it there will necessarily come more or less of the fluid muck, which, settling to the bottom, must be removed by dredging.

4—FORMATION OF MARINE MARSH LANDS.

This is a process still going on from year to year at the head of the Tintamar and Missiquash rivers. It has been stopped on the Au Lac and Laplanche by the "aboideaux" under the post road and Intercolonial Railway. There is a tide feeder on the Missiquash, on the north side of the canal, for converting marsh lands into arable lands. They are of no value until fertilized by the sea, and since, by Mr. Page's plan the sea is excluded, this process will be stopped, and no more marine marsh land can be formed on that side of the canal.

5—WATER SUPPLY.

Of the sufficiency of the reservoirs, which, according to Mr. Page's admission, provide storage for only six and a half days' supply, while spring tides occur at intervals of fourteen days, it is not my intention at present to offer any opinion.

I have, however, to remark that, applying the same line of argument to the silting up of the reservoirs that he has to the lakes at the head of the Laplanche, they must ultimately be filled up and cease to be reservoirs.

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There are other objections which might be urged against Mr. Page's plan, but having stated the leading ones I will not trespass further upon your space and the time of your readers by referring to them.

In my next I propose to enter upon a defence of my own plan.

BROCKVILLE, May 7, 1874.

IV.

To prevent any misconception of my plan for the Baie Verte Canal, it is necessary at once to say that I do not propose to construct a canal accessible at all stages of the tide. For sufficient reasons, given in my several reports, none of which have been controverted, it is recommended that it should be accessible only at and after half tide from Cumberland Basin, though at all stages at Baie Verte. The only conclusion to be drawn from the facts reported is, that whether the terminus in Cumberland Basin be at Au Lac or at Laplanche, a half-tide canal is all that can be attained, and that such a canal is sufficient for all practical purposes. At the same time, however, I have shown that when the trade demands further accommodation, the locks at the western end can be duplicated, and as many vessels can be passed through them in twelve hours as in twenty-four hours at the eastern entrance.

In noticing the Chief Engineer's criticisms upon my proposed line from Laplanche to Weeks' Head, I shall do so in the same order as when treating of the Missiquash and Tidnish line.

1—THE WESTERN ENTRANCE.

"Adverse winds blowing across the channel, dangers near the shore, and fogs, are some of the perplexing difficulties certain to be experienced in making or leaving the proposed entrance. These facts," says Mr. Page, "there is good reason to believe are practically known to many who may have occasion to navigate that part of the coast.

It must certainly be admitted that no sailing vessel can make or leave Laplanche, or any other port in "adverse winds." But adverse winds and fogs are just as likely to be encountered at Au Lac as at Laplanche, and so we may at once dismiss these trivial objections.

The "dangers near the shore" are "the stumps and roots of an underground forest," and also large masses of stones scattered along the beach, and "rock in position," where the entrance pier is to be placed at the depth of three feet above the bottom of the half-tide canal.

The stones and stumps were observed by me at low water, but did not, by any means, appear to be so dangerous as represented by Mr. Page. The stones will all be required to fill the pier, and the stumps will be out of the track of vessels. But should they become inconvenient to the navigation, they can easily be removed.*

With regard to the rock at the entrance, Mr. Page makes the uncalled for remark, that I was either ignorant of its existence, or knowing it, had failed to communicate the information.

In the discussion of a purely scientific question, the use of unprofessional language does not in any way assist in its elucidation, and is altogether a matter of taste. It would appear, however, as if he considered the discovery of the rock fatal to Laplanche as an entrance for the canal.

* DAWSON, in his GEOLOGY OF NOVA SCOTIA says these remains of the submarine forest can be "cut with the spade." That being the case, they cannot be dangerous to vessels navigating this coast.

The information I received from my assistant is directly at variance with that Mr. Page received from him. The section at the entrance furnished me, exhibits borings from eleven to twenty-two feet below the bottom of the canal at this entrance, and having no reason to doubt its correctness, provision was accordingly made for supporting the pier upon a close pile foundation, which would also prevent it being undermined by the current. But if rock *in situ* be found at three feet above the bottom of the canal, it will rather be a benefit than otherwise. It will give a solid foundation for the pier, thereby saving the cost of the artificial one, and the cutting of a channel through its crest, which will be laid bare at low water, will furnish stones for filling the pier at the very cheapest rate. It will make a sure, solid pier, at less cost than if formed upon clay.

If anything further were required to demonstrate the entire safety and feasibility of this entrance, I can add a kind of proof that must commend itself to the understanding of all men—the evidence of practical and intelligent men living in the immediate vicinity, who are well acquainted with the navigation of Cumberland Basin up to Laplanche, and beyond it to Minudie. After I had completed my general report, I received several communications from Nova Scotia, which so emphatically confirmed my views that I deemed it important, in the interest of the country, to place them on record in the department. They were nine in number, giving the observations and experience of shipowners, shipmasters, seamen and merchants, and coming from practical and experienced navigators must be accepted as reliable.

They state that Laplanche will make a better entrance for the canal than Au Lac. That from many years' experience, and some from making as many as sixteen trips both ways every year for many years, they never heard of any disaster to shipping at this place, or between it and Au Lac; and that the Minudie flats form a natural breakwater for the proposed entrance, and there being no harbour at Au Lac, vessels seeking shelter must make for the lee of the Minudie marshes.

2—THE EASTERN ENTRANCE—BAIE VERTE.

The section of the location, furnished me by my assistant, shows a cutting of a mile in length across Tidnish Head, requiring about 400,000 cubic yards of excavation. Instead of wasting this large mass of material in spoil bank, and covering up valuable lands, it is intended to throw it into the sea—not in the deep sea, but to utilize it in the formation of a sea embankment in the tideway of the bay between Tidnish and Weeks' Head; the entrance lock to be placed at the limit for low water, and under the lee of Weeks' Head, the entrance piers extending out thence to fifteen feet depth of water, at low water, and another embankment, running from the lock to the shore, forms a large and commodious inner basin, the surface of which will be five feet above high water.

There is a bay of two miles in extent from Tidnish to Weeks' Head, and another of one mile between Weeks' and Jackson's Head, the latter opening out a little to the south. There are shelving rocks at each of these points running out to deep water, and above the rock, the clay and gravel forming the bluffs or heads, rise to a height of from twenty to forty feet.

In my second letter the objection was urged against the Au Lac and Tidnish line, that its entrance on Baie Verte was in a *cul de sac*. In order to avoid this, and give plenty of sea room, I proposed placing the entrance to my line two miles to the eastward, just under the lee of the reef running out from Weeks' Head, where the piers extending out in a north-north-east direction will be placed along and parallel to the

reef, so as to avoid rock cutting, at the same time giving protection to the sea embankment from the easterly winds, the bay being shut in from northerly and westerly winds by Cape Tormentine, as previously stated.

Here it is necessary to draw special attention to a fact that bears directly upon this plan for the Baie Verte entrance. In his last report the Chief Engineer has made the important correction in the departmental chart of Baie Verte referred to in my second letter, which adds about two feet to the available depth of that bay more than the chart originally represented.

Having accepted this chart as the basis of my plan, if I am now to accept the correction—and I see no alternative—my plan must be modified to meet the altered conditions. As a consequence of this correction, the Chief Engineer has reduced the length of his piers from 9,200 feet to 4,000 feet—to less than half. If he is warranted in making this very great reduction in the cost of the work at Baie Verte, I shall also be warranted in doing the same. Both the length of the sea embankment and that of the entrance piers can be curtailed, and the entrance thrown more into the bay between Weeks' and Tidnish Head, whereby without abating the amount of sea room for vessels to any inconvenient extent, the cost of the work can be very much reduced.*

The Chief Engineer offers the two following objections to my plan, namely, that it "would be nearly, if not altogether impracticable," and if executed "would not long continue to answer the purpose contemplated." These, however, are mere opinions unsupported by any proof. No facts are adduced, such as "rock in position," or quicksand to render the undertaking dubious, only an array of imaginary difficulties, and conjectures regarding certain contingencies that may, or may not arise in the progress of the work.

In support of my own opinion as to the sufficiency of my plans, I can confidently refer to the records of the past, to the canals and other public works, not only projected by me, but constructed under my own directions, when for a period of thirteen years I filled the position now occupied by Mr. Page, works now in successful operation, and which are, at this day, the indispensable and unrivalled highways of our commerce.

In my next I will refer to the line of canal itself.

BROCKVILLE, May 11, 1874.

V

Before speaking of the canal itself, I am induced by Mr. Page's reference to Captain Crawley to indulge in a slight digression.

In the statement of any engineering problem, it is always necessary to be exact.

To omit important facts bearing upon the question, or to place others in such a light as to lead to wrong impressions, and then to draw conclusions from such premises is not the way to arrive at the truth. Yet in my last it was clearly shown that in this way Mr. Page treated the question of the western entrance to the Laplanche line, and proved to his own satisfaction that the same coast, which had been navigated without accident for the last forty years, is now unsafe.

His reference to Captain Crawley's scheme is characterized by the same method. He states in effect that my plan of operations was plagiarized from Captain Crawley

* This correction enables me in fact to make some very important improvements in my plan. By separating the entrance piers some two or three thousand feet, and placing the eastern on the crest of the rocky ridge jutting out from Weeks' Head; and the western deeper in the bay, the entrance will not only be enlarged but it will be better protected from easterly winds, while the sea embankment will be reduced, and the whole made more secure.

—that it is indetical with the crude idea which, thirty years since, was suggested, discussed, and discarded by him, and that I now "claim its paternity."

In reference to these statements, it is only necessary for me to draw attention to the printed official documents in which the respective suggestions are elaborated, and to point out the fact that Captain Crawley's scheme is entirely different from mine—that he did not contemplate the formation of a canal with locks at each end, to form a slack-water navigation, in the way I propose, but merely considered the probable effect of opening a channel through the Isthmus, and "leaving it to the waters themselves to complete the communication, and render it navigable." He did not propose in any way to direct and control the currents. His channel was to form an artificial strait or arm of the sea, and Nova Scotia was thereby to become an island in the Atlantic. Finding this would not answer, he dismissed the idea as unworthy of further consideration.

My general report, describing the process which is an essential feature of my plan, does not bear the construction that I claimed any originality for the suggestion. The effect of a tidal scour which the Chief Engineer treats so contemptuously, was well known to the profession long before it was discussed by Captain Crawley, as one of "the great sources of power in nature" ever in operation. In our own day it has been turned to good account for improving the channels in the tideway of many rivers in Britain. The only object served by Mr. Page's simulated zeal for Captain Crawley's interest in a worthless suggestion is to divert attention from the real question at issue—the efficacy of a tidal scour.

3—THE CANAL ITSELF.

It is stated as the third objections to my line that along the valley of the Tidnish it is "extremely crooked, and the damming of the river would flood the low lands for several miles.

The dam at the mouth of the Tidnish is similar in position, and serves the same purpose, as the dam across the twelve mile creek at Port Dalhousie on the Welland Canal. While it is the safest and most economical way of providing a channel, it can be so straightened by cutting across the points as to render its navigation easy. There are many parts of the Welland Canal where the curvature is much greater than it will be here. Practically it is of very little account, and cannot with any show of reason be urged as an objection to my line. In the matter of safety it far exceeds the Missiquash line, which is thrown into side cutting along the Tidnish, and, therefore, liable to breaches from leaks, springs or slides in the banks. The preservation of straight lines for a canal is of less importance than economy of construction.

The land that will be overflowed by this dam is of limited extent, and for the most part of inferior quality—the banks being high on both sides of the Tidnish, and the valley between them narrow, while a large portion of the land is unfit for cultivation.

Apart from this, however, the cost of the land that may be flooded is embraced in my estimate.

Under the same head, it is objected that "by keeping the water in the summit level at the elevation proposed, the drainage of the marsh lands between Long Lake and Cumberland Basin would be obstructed."

The drainage of the lands along the Laplanche will not be obstructed by my plan. The canal being isolated from the river, the drainage on the south side of the canal flows away from it by its own natural channels to the aboideau near Amherst, while that on the north side, which is of limited extent, followed by the side ditches up

to the head of Fort Lawrence Ridge, from whence the, low uncultivated marsh lands can easily be drained, by the north side of that ridge into the Missiquash. But the drainage of these remote and worthless bogs and marshes is altogether a matter of secondary consideration, and must not be allowed to interfere with the best arrangement that can be made for the canal.

4.—SCOURING OPERATIONS.

In my general report, accessible to all, will be found a full statement of the proposed method of proceeding with the work. It may be briefly stated here that it is intended in the first place to open a channel through the Isthmus, and let the high water of Cumberland Basin flow through it to Baie Verte—that according to the state of the tides the fall at high water will vary from fourteen to twenty-four feet in the distance of eighteen miles from shore to shore, producing a velocity, if uniform throughout, varying from two to five and a half miles an hour, the least of which, it is well known, is sufficient to sweep along sand, gravel, and rounded pebbles. The scour may be increased checked, or altogether stopped at any time, and twice a day the channel will be laid bare for inspection, so that its progress may be seen and regulated, until the channel is sufficiently enlarged for navigation, when the locks at either end will complete the canal.

In a previous letter it has been shown that no progress can be made in the excavation of a running sand, by the ordinary methods. But it can easily be washed away by a moderate current. The floating bog and fluid muck can also be removed most economically, and most effectually by the same means.

In a subsequent report, not printed, some observations were made, from which the following are taken :

The surface of Long Lake, which is seven miles inland, is forty-two feet above low water at Cumberland Basin, and twenty-two feet above the bottom of the canal. That, and the other lakes at the sources of the Laplanche, have an aggregate area of five hundred and sixty acres. Then, since the effective scouring power of water is in direct proportion to its volume, its level with reference to low water, and the number of times it can be used throughout the year ; and, since the whole forty-two feet falls within the range of the tides, it will be observed that, even before the water-shed is cut through, a great power is available for scouring out this portion of the channel. That it will be sufficient to wash out all the clay, sand and earth within the prism of the canal, everything in fact, except the rock, stones and hard pan, there can be no doubt ; and the moveable material on which this current will act, constitutes more than nine-tenths of the whole mass.

It was further observed that since devising this scheme of the *modus operandi*, my views have been exemplified and confirmed by the history of the scouring operations on the river Lune in Lancashire, given by David Stevenson, M. Inst. C. E., in his recent work on "Canal and River Engineering, 1872." The object of improvement on that river was, by removing obstructions and making training walls, to regulate the currents so as to insure a fixed channel of greater depth. He says, "I found by dredging a few hundred yards of hard material, or erecting a short wall, thousands of this soft material are scoured away by the action of the current alone. In all river improvements this is an effect which should be fully taken into consideration by the engineer, especially in forming his estimates." Then referring to the plan, he adds : "By dredging the upper shoals of that river, the whole lower part of the river was deepened by the natural scour, without entailing any expense in removal."

The Chief Engineer of the Department of Public Works does not advance any argument against this plan of operations. He treats it simply with incredulity, as if it were a matter entirely beyond his comprehension.

In my next I intend to conclude my remarks on the Baie Verte Canal.
BROCKVILLE, May 18, 1874.

VI.

The next subject in order is

5.—THE WATER SUPPLY.

Under the fourth head of Mr. Page's objections to my plan for the Baie Verte Canal, he remarks that the introduction of the waters of the Bay of Fundy directly into the canal would have a tendency to silt up the channel, and that the filling of the lakes to give the necessary supply for the navigation, in the manner proposed, would be attended with certain failure.

It would be out of place here to follow Mr. Page into all the details by which he has endeavoured to support these statements. I shall, however, refer to a few leading points in the discussion, as well as to certain known facts, with which they are wholly irreconcilable.

If it will take as many hundred years to silt up the canal after it is once open, as it has to form the Cumberland marshes, according to Professor Dawson, then there is no likelihood that in our day there will be any obstruction to the navigation from this cause. According to my plan, however, the same effectual means will always be available for removing such deposits as are proposed to be used for scouring out a channel for the canal. The silting up of the lakes will scarcely be observable; indeed, more material is likely to be washed out of them during the scouring operation and by rains, than the high waters of the Bay will ever replace.

With regard to the supply of water for the navigation, it will not be denied that there is some certain level for the canal between the second and third locks, at which it can adequately be supplied and maintained by the high waters of the Bay of Fundy. The main supply must of course come from that Bay, but still the fresh water of the inland lakes forms a convenient and important addition not to be neglected. Mr. Page has assumed eleven feet below high water in the Bay for the low water level of the canal, while I have assumed ten feet for the same. He allows for a fluctuating level of three feet in the canal, I allow six feet. What may ultimately prove to be the best working level, it is impossible for any engineer at this time to say. The operations in this respect must, to a certain degree, be tentative; and on this account, I have placed the sills of the second and third locks so that, if necessary, the summit may be reduced to thirteen feet below high water of the Bay. By the tidal scour this difference of three feet can be attained without much additional cost, while by the ordinary process preferred by Mr. Page it would be a very formidable item of expenditure.

Mr. Page has stated, that if the lakes were once reduced to the low water level of the canal (10 feet below springs) they could never be replenished again by all the water that could pass through the full surface width of the canal. By this "sweeping statement" he imagines he has proved the "certainty of failure" in the means proposed for supplying the summit level, and that it is "sustained by the elevations of the tides." This statement, however, rests upon a "theoretical solution" of the hydraulic question submitted, the results of which are liable to error, and can never be relied

upon with the same certainty as those afforded by examples of similar engineering works now in operation.

As a case in point, with which this opinion may be compared, and by which it can be tested, let me refer to a canal now in existence, supplied directly from the sea.

The Suez Canal, opened in 1869, is one hundred miles long from Suez to Port Said. Its surface is on a level with the sea. It has no locks, gates or artificial works to regulate the water. The bottom width in cuttings is seventy-two feet, depth twenty-six feet, and slopes two to one; but a large portion consists of lakes, formerly low lying tracts of country, below the level of the sea, covered with salt. Lake Timsah, about half-way across the isthmus, is about five miles long and one mile wide. The Bitter Lakes are about twenty-three miles long, and from two to six miles wide. The former was first filled from the Mediterranean, the latter from the Red Sea, and on being united by the canal the water rose in Lake Timsah four inches, and there was a constant, though moderate, flow towards Port Said. This was due to tidal phenomena of the Red Sea, there being no tide in the Mediterranean.

From the Admiralty report on the tidal observations in this canal, we learn that "the results show that in the southern portion of the canal, between Suez and the Great Bitter Lake, the tidal influence from the Red Sea is felt, there being a regular flow and ebb, the flood running in about seven hours, and the ebb running out five hours. At the Suez entrance the rise at springs, unless affected by strong winds, is between five and six feet; about half way from Suez to the Small Bitter Lake, a distance of six miles, it is under two feet; at the south end of the Small Bitter Lake, a few inches only. [This information is derived from David Stevenson's work on "Canal and River Engineering."]

The amount of evaporation from the surface of this canal is measured by the two hours length of flood in excess of the ebb, and is many times greater than the greatest daily demand for lockages on the Baie Verte Canal. Still it is observed that the Bitter Lakes are not only kept full, but that there is a constant flow through them towards the Mediterranean. The question is here presented, how much higher could the surface of their lakes be kept if there were gates that could be closed at the turn of the flood, so as to stop the five hours reflux of the ebb? But taking the conditions of the tidal phenomena as they exist, the fact is known that the canal and lakes are kept up to an elevation varying from five to six feet under the high water of springs in the Red Sea.

The Bitter Lakes are situated about twice as far inland as Long Lake, and present a water surface eighty times greater than the Laplanche lakes. If, without any artificial means of preventing the waste of five hours' reflux, they can be kept up to that level, then *a fortiori* the level of Long Lake can be maintained at half the distance, and without any waste, at an elevation, certainly not exceeding five feet under high water of the Bay of Fundy, and that will give twenty-one feet of water in the canal, or twenty feet available draught.

In concluding this part of the subject, it may be observed that the entrance to the Laplanche line being situated between two rivers, the Laplanche and the Missiquash, it offers greater facilities for obtaining a water supply than the Missiquash line. On my plan supply gates admitting and retaining all floods can be advantageously placed on the north and south sides of the canal, communicating by short channels with both rivers, and thus increase the flow to any desired extent. This mode of supply is cheaper,

more effective and less complicated than the series of dams, bulkheads, weirs and sluices proposed to be employed on the Missiquash line, for skimming off the clear waters of the Bay of Fundy and feeding the canal through the intervention of storage reservoirs.

6.—THE ESTIMATE OF COST.

"The omission of numerous essential items of work, and the insufficiency of the estimate to meet the expenditure on the works enumerated, has a tendency to mislead as to the probable cost." In the previous part of his report these omissions are enumerated.

1. The dredging at both entrances. This is included under the head of "earth excavation" in my estimate.

2. Back ditches for draining the lands. These are particularly specified, and are included under the same head as the preceding.

3. Mucking and clearing the seats of the banks. This is also specified, and included under the same head.

4. Slope walls for the protection of the banks. There is no immediate necessity for slope walls on the first opening of the canal. It is not necessary, nor is it usual in works of this kind to provide them at the beginning, nor until they are actually required. To this day there are none on the Suez Canal, which, as a highway of commerce, is of much greater importance than the Baie Verte Canal ever will be.

Upon the whole, therefore, there are no omissions, and the prices allowed for the work are sufficient to cover the cost, even supposing that "the whole of the earth-work, including sand, clay and muck, shall be removed by manual labor or by mechanical means," as stated in my general report. Hence it appears that Mr. Page has unnecessarily added upwards of two millions of dollars to my estimate for alleged omissions and insufficiency of prices, and is still compelled to admit that my line will cost \$600,000 less than his. These facts all go to prove what I still confidently maintain, that I know I have selected the best line for the canal, and that it can be constructed in the most permanent and efficient manner at a cost not exceeding five millions of dollars.

Appended to the Chief Engineer's report is a private letter of mine addressed to the late Minister of Public Works. As no reference whatever is made to it in the body of the report, I am at a loss to understand the reason of it being there; but it must be apparent that its publication is a breach of that confidence which should exist between gentlemen engaged in the public service. Still there is nothing in the letter, although written in the freedom of the unofficial style, that I would desire to withhold from the public. It only anticipated the unfair treatment my plans would receive from the officials of the Department, so clearly exemplified by the controversial tone pervading the report of the Chief Engineer.

Whatever comes of the Baie Verte Canal, the country has gained, through my intervention, the abandonment of "the original idea" which would involve an expenditure of twelve or fifteen millions of dollars. I would like, before the Dominion is pledged to the modified idea, to advance one step farther, and have the respective plans submitted to a board of competent engineers for final decision.

Having now concluded the subject of the Baie Verte Canal, I have to thank you for so kindly allowing me space in your journal for the discussion of this important question.

BROOKVILLE, 21st May, 1874.

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VII.

Other business has prevented me sooner resuming the subject of our canals. My previous letters referred only to a projected work, on which no expenditure had been incurred, except for the preliminary surveys. They were designed to caution the Government against embarking in an impracticable scheme, and wasting public treasure upon the "final location" of the Baie Verte Canal. In turning now to

THE WELLAND CANAL,

I have to deplore faults already committed in the enlargement of a great national work, now in progress—faults persisted in too, contrary to the advice of the Board of Engineers, and for which they cannot, in any way, be held responsible.

As one of that Board I feel it necessary to say for myself, that while in my professional capacity my duty was performed when the opinion asked for was given; yet as a Canadian, having the best interest of my country at heart, I have a right to give expression to my settled belief that our Government was ill-advised when it adopted Mr. Page's plans without modification after their defects had been so plainly pointed out by the Board of Engineers.

At a time when public attention throughout the Western States is earnestly directed to the important question of securing cheap transport for their products to the Atlantic seaboard, and the relative advantages of every line of communication are receiving the closest scrutiny, it is incumbent on our Government to see that the capabilities of our geographical position, as a channel for this trade, are not impaired or neutralized by engineering blunders; but that on the other hand, the best modes of construction, and everything that art and skill can do, shall be employed to maintain the superiority of the St. Lawrence route, as the great natural outlet of the States which lie within its own watershed.

The chief defects of the plans for the new line between Thorold and Port Dalhousie, as pointed out by the Board of Engineers, are:

1. There will be a *diversity* of lifts in the locks, where there should be a *uniformity*, thereby rendering it more difficult to maintain the navigation, and to economize and regulate the flow of water.

2. In consequence of this defective arrangement there will be *twenty-four* locks instead of *twenty* on the line between Thorold and Port Dalhousie, or *four* locks more than necessary had all the lifts been uniform, as recommended by the Board of Engineers. And as regards the navigation, every additional lock may be reckoned as an additional mile of canal. From this cause alone, *every* vessel that passes through the canal will be unnecessarily delayed.

3. As the locks can be filled and emptied only through the lock-gates, and not through the lock-walls also, as recommended by the Engineers, there will necessarily be a further delay to the passage of *every* vessel at *every* lock, beside the danger of accident to the gates from the surging of the vessel when water is admitted in only one direction.

4. There will be two reaches on the new line without proper basins, as recommended in the report of the Canal Commission. In these reaches the canal surface is so limited that a single lockage will lower it thirteen inches in one and twenty inches in the other; and in order to keep it up to prevent the grounding of vessels, a large body of water must be kept running to waste outside the locks.

Some minor defects in the plans were alluded to, but not specially mentioned by the Board, as it was considered they would naturally occur to the practical engineer charged with the duty of carrying out their suggestions.

I have done all that lay in my power to avert the injury to the canal which it must inevitably suffer from these grave defects in the plans. After it was known that the recommendations of the Board of Engineers were not adopted by the late Government it was thought advisable to bring the matter under the notice of the present Government in hopes that the decision might be reconsidered. With this view I joined with one of my colleagues in pointing out more distinctly to the Minister of Public Works the injurious consequences to the navigation of persisting in imperfect plans. This was done by letter dated the 17th December last, when as yet it was not too late to adopt some, if not all, of the suggestions of the Board. Since this appeal was made without effect, it would seem either that the question is not properly understood, or that it was considered of more importance to this country that the consistency of a public department should be maintained than that the enlargement of the Welland Canal should be made efficient, and so a noble work is to be marred by defective construction. It is right, therefore, that these facts should be publicly known, as justice to myself and to my colleagues requires that we should be relieved from all responsibility in the matter. This is the more necessary as it may be imagined by those not familiar with the blue book that the works are now proceeding in accordance with the recommendations contained in the reports of the Canal Commission and Board of Engineers. This, however, is not the case. In some important particulars, both the letter and the spirit of these reports have been so far departed from that the enlarged canal will prove defective in some of its most essential qualities as a means of cheap and speedy transportation.

The report of the Canal Commission presented to the Government in February, 1871, settled all the more important questions relating to our canals—the scale of navigation for the respective lines—the canals to be constructed—and the order in which they should be undertaken and proceeded with. Its recommendations generally were adopted by the Government, and were accepted by the country at large.

Respecting the Welland Canal it recommended no departure from the existing line, except that between Thorold and Port Dalhousie, which became necessary in order to obtain sufficient room for placing the new locks at suitable intervals, with ample basins between them to admit of the free passage of vessels, and capable also of holding a large body of water, the level of which should not be unduly affected by the lockages.

And, although this new line was recommended, it did not contemplate the abandonment of the old one between the points of divergence. On the contrary, it was stated that for the class of smaller vessels it will be advisable always to maintain the existing line of locks, and to keep them in good working order; and as this could be accomplished at a moderate expense by merely raising the lock walls and canal banks to give the same draught, twelve feet, as for the enlarged canal, it was recommended to be proceeded with at once, and thereby secure an immediate advantage to the trade.

It will be observed that the first of these recommendations has not met its entire fulfilment in the plans for the enlargement recently placed under contract; and as regards the second, it does not appear that any active measures whatever have been taken to secure the great advantage of the increasing draught in the mountain range of locks, *already* available on the summit level. As the immediate effect of the latter improvement would be to increase the carrying capacity of vessels navigating the canal by one hundred and fifty tons, that is, from five hundred to six hundred and fifty tons net, it seems to me that it rests with the merchants and Boards of Trade to

advocate an improvement in which they are so directly interested. I intend therefore to limit my remarks to the first of these recommendations.

The surveys for the enlargement of the Welland Canal were in progress when these recommendations were made, and about a year afterwards, in April, 1872, the Chief Engineer submitted his report. Towards the close of that year the plans for the new line were so far advanced that a portion of the work was advertised for tender. Then it was that public attention was more particularly turned to the official plans for the enlargement—that Mr. Grenville produced his scheme for a shorter line with combined lock—that the old project of the lateral cut to Niagara was revived, and that another from Chippewa to Niagara was brought forward. These several projects were discussed in the public newspapers with so much ability and earnestness that the Government considered it expedient to refer the whole question to a Board of Engineers. Accordingly, in January, 1873, Mr. Gzowski and myself were requested "to examine the proposed enlargement as indicated in the plans and in the specifications of the Engineer, Mr. Page," and also to "consider any other plan or scheme" which had been suggested to the Government, and we were authorized to call upon the Hon. W. J. McAlpine for his counsel and advice in the matter. Our report was submitted in February, 1873. Its conclusions in reference to alternative plans were received, but our suggestions for rectifying the errors of the departmental plans were entirely rejected. It is now proposed to examine the official statements and arguments by which the responsible officer of the department succeeded in upholding his plans against the recommendations of the Board of Engineers; but before doing so it may be well to recount the preliminary action of this Board.

When about to proceed to an examination of the line and plans, the Board at their first meeting in Toronto invited the Chief Engineer to accompany them, and give them the benefit of such information as they might call for, and which in his official capacity, he was qualified to offer. It was due to him in his responsible position that he should have an opportunity of being present when his plans were under discussion.

When doubts arise as to the sufficiency of an Engineer's plans, or where the magnitude of the work renders it desirable to seek the best advice, and a reference of this kind takes place, the advantage of a conference is obvious. If both parties desire to adopt the best arrangements and the best modes of construction, a little discussion is likely to bring about harmony of action, and if all agree upon a particular course, the question is settled at once, then and there, greatly to the advantage of the public service. As a public servant it was undoubtedly the duty of the Chief Engineer to meet the Board appointed by the Government. If his plans were sufficient they would be sustained, but if defective, no one should be more desirous to have them corrected. Mr. Page, however, declined to attend, and by that act assumed a grave responsibility.

Our report was first referred to Mr. Page, and then extracts from his report thereon were sent to Mr. Gzowski and myself, which we declined to answer, stating that we could not, under the circumstances, enter into any discussion with that officer, but declared our adherence to the opinions previously expressed. By the course adopted the Government lost the benefit of our criticisms upon the statements and arguments contained in the Chief Engineer's report of the 12th March, 1873. But that which we could not with propriety undertake to do collectively, I feel myself at liberty individually to take in hand, because it has become a question of deep public

concern, and it seems right to me that the public should be properly informed on this important subject. In my next, therefore, I shall, with your permission, proceed to an examination of the report above referred to.

BROCKVILLE, 23rd July, 1874.

VIII.

For convenience of reference as well as to save making long extracts, I have numbered the paragraphs of the Chief Engineer's report of the 12th March, 1873, as printed in the Parliamentary blue book, from 1 to 109. If any of my readers wish to identify them, it is easy to pencil the figures in the margin of that report.

The introductory part, clauses 1 to 16, might be passed over without remark, as irrelevant to the question, but for the clauses 11, 12, and 13, in which Mr. Page controverts the statement made by the Board of Engineers, "That the line as located is nearly that indicated by the Canal Commission."

Since the new line does not diverge from the old one at Thorold, as suggested by the Canal Commission, but at Marlett's Pond, about one mile south of that village, it is an unquestionable fact that it is not exactly the line recommended, but corresponds nearly with it. So it will be seen that the dates mentioned for the commencement and completion of the survey, and his verbal communication to the Board do not in any manner affect the perfect truth of this statement.

But if Mr. Page means to assert that the Commission was in any way indebted to him for the suggestion of the new line, he is equally in error. It was very little information indeed that the Canal Commission received from him, and the writer of their report was himself too well informed on the subject to require any of his suggestions. Many years before this survey was begun he well knew, from his long and intimate acquaintance with that part of the country, the course which the enlargement ought to take, and had often referred to it. If Mr. Page had followed the recommendation of the Canal Commission, and run his line from Thorold instead of Marlett's Pond the country would have been saved a great deal of unnecessary expense, and the enlargement would have proved more efficient.

The Board of Engineers are taken to task (in Nos. 14, 15, and 16) for having gone so thoroughly into the questions submitted to them. They are told, in effect, that they ought to have confined themselves to general principles, and not to concern themselves about details—such being the proper duty of consulting engineers.

This admonition comes very oddly from the responsible officer of the department, whose plans they had proved to be defective, and who had himself declined to meet the board and discuss the matters referred to. The board did not feel called upon to enter into a disquisition upon first principles. It was sufficient that from a perfect knowledge of these they should first point out the error of Mr. Page's plans, and then offer practical suggestions for avoiding them. An essay on the fundamental principles of Civil Engineering may have its proper place in elementary works on that science, but the practical application of these principles to the business in hand is all that Engineers of good standing are expected to be concerned with.

The reference to the question of combined locks (Nos. 17 to 28) might also be passed over as irrelevant but for the misstatement in No. 18, and the erroneous conclusions arrived at in Nos. 19, 20 and 21. In No. 18, Mr. Page says the Engineers gave "no reasons" for rejecting the introduction of combined locks on the Welland Canal, and in order to supply this alleged deficiency he submits his own views on the subject.

Any one who has the blue book to refer to can readily see that the 18th clause is incorrect, for at page 88 of the Parliamentary reports the reasons are fully stated by the Board, and are conclusive; while those added by Mr. Page are in many instances erroneous. The statement made in the 19th clause meets its practical reputation in the existence of a flight of eight locks connected, on the Caledonian Canal, popularly known as "Neptune's Staircase," a noble monument of Telford's engineering skill. This weak attempt to add more conclusive reasons for rejecting combined locks is an utter failure, as it leaves many important considerations out of the question. The relative cost of distributed and combined locks on single and double lines; their effect upon the time of passage; economy in the use of water; its proper regulation in the reaches, and the relative efficiency of the different systems, are questions not to be fully discussed within the limits of an ordinary official report.

THE LOCATION AT THOROLD.

(Clauses 29 to 33.)

In setting about the location of the new line at Thorold, the Engineer had two points of departure from the existing canal to consider; but in both of these he should have been governed by the same conditions as to efficiency. First, of providing ample water surface in every reach. and second, of making the lifts of the locks uniform; and a third condition, that of economy of construction must not be disregarded.

As regards the canal, everyone of these conditions would be fulfilled by diverging from the old line at Thorold on the basin below the upper lock. This line would give ample basins between the locks—uniformity of lifts—save the cost of a new guard lock, and half the cost of cutting a new canal through the ridge dividing the ten and twelve mile creeks, a mile of heavy work through rock and clay.

The objections to this line would be, *first*, the purchase of two mills, and the alteration of the machinery of three others to suit them to the change of level; and *second*, it will be necessary on this line to cross the Welland Railway on its maximum gradient of eighty-three feet in a mile. The first objection is resolved into a mere matter of expense—the second to a question of practicability to be referred to in my next letter.

The governing conditions of the location are for the most part reversed by diverging from the old canal at Marlatt's Pond. The Board of Engineers pointed out the fatal defects of this line by stating that "there are two reaches here where it is impossible to have outside basins except at a very large cost in deep rock cutting, and where the canal surface is so limited that a single lockage would have the effect of lowering the water thirteen inches in one and twenty inches in the other, and where, in order to prevent the grounding of vessels, it would be necessary to run a large body of water through the waste weirs outside the locks." Further objections to this line are found in the inordinate cost of cutting through the ridge, building another guard lock, and shifting the line of the Welland Railway.

As the only means of avoiding this complication and securing an efficient canal, the Board of Engineers recommend a change of location, "That the line for the enlargement shall follow that of the existing canal through the little deep cut to Thorold, and after descending into the first basin between the two upper locks, sweep round to the north of the village, and unite with the proposed line somewhere below Brown's cement quarry."

Mr. Page, in clause 29, misstates the case by saying "the Engineers suggest a change so that the enlarged canal shall pass through the village of Thorold;" and he repeats the same statement in No. 70, implying that to take the canal through that

village was the first consideration. Then he adds, "the principal reasons given for this being that they consider the arrangement of the locks objectionable."

It was not to make the enlarged canal pass through Thorold, but to get rid of a serious defect in Mr. Page's plans, a defect which he himself admits in clause 58, that this change of location was suggested, and he most unwarrantably assigns the wrong reason for it, when he puts it on the ground of their objection to the arrangement of the locks, instead of the want of basins on his line.

Exception was taken to Mr. Page's plans mainly on two grounds. First, diversity of lifts for the locks; and second, want of basins on every reach. Uniform lifts might then, and may still, be had on his own line; but on that line it is impossible to have basins on every reach; and as this condition was considered imperative, a change of location became necessary.

DIVERSITY OF LIFTS.

It is some relief to find that Mr. Page repudiates the "medley of lifts" exhibited on the profile of the new line laid before the Board of Engineers, but I must still characterize as bad engineering the diversity of twelve and fourteen feet lifts to which he still adheres, and the four unnecessary locks so unwisely imposed upon the enlargement.

Although in his first plan of the canal Mr. Page proposed to have three locks of sixteen feet lift each at the lower end of the line; and although the resident Engineer suggested seven locks of sixteen feet lift in lieu of the eight locks of fourteen feet lift each at the upper end, still the Chief Engineer states in clause 68, that locks of sixteen and seventeen feet lift are "at variance with precedent," and after citing several examples, he adds the absurd remark in No. 88, "that there is no case on record, as far as I know, in which an experienced engineer, after due consideration, has advised the construction of locks of seventeen feet lift, on a line of navigation of such dimensions as that of the enlarged Welland Canal, and where the gates require to be so expeditiously worked."

In reply to this I have to say, that if engineers are confined to precedent, there is an end to all improvement. George Stevenson had no precedent for the locomotive, nor his son for the Britannia Bridge—Roebing none for his Niagara Bridge, or Captain Eads for the St. Louis Bridge. The science of the engineer enables him to extend the same principles which underlie all methods of construction to new and improved and greater works for man's benefit; but according to the light of the Public Works Department the profession is to stand still, and undertake nothing without example. While the railway service is stimulating mental activity to the utmost in the production of greater facilities for travel and transport, the hydraulic engineer must not advance a single step—there is to be no further progress, and the only safe guide for the administration of the great public works of this Dominion is the prejudice of example.

But in clause 80, Mr. Page refutes himself by giving an example. It seems we have been using with perfect safety and success, ever since the Grand River level was adopted on the main line, locks of seventeen feet lift at Port Robinson and Welland. If this can be done with locks of 26½ feet width, we have only to make the gates proportionally stronger for locks of forty-five feet in width. Then again, as the gates can only be moved when the pressure is withdrawn, and they should be sufficiently buoyant in either case to move easily, there is really no difference in the time of working them. In fact, gates for locks of sixteen or seventeen feet lift can be made quite as safe, and

can be worked quite as expeditiously as those of twelve and fourteen feet lifts. This is not merely my own opinion, but the opinion of the Board of Engineers, and if our views had been adopted the new line would be better served, and be rendered more efficient with twenty, than with twenty-four locks. Either for want of scientific knowledge, or for lack of skill and courage in applying it, the Dominion is about to construct four unnecessary locks on the Welland Canal, at a cost exceeding half a million of dollars, and thereby adding in perpetuity twenty per cent. to the time of passing the locks, and twenty per cent. to the annual cost of working and maintaining them.

In my next I will consider the questions of basins and the railway crossings.
BROCKVILLE, July 25, 1875.

IX.

BASINS.

That outside basins of adequate capacity, on the shorter reaches, are an indispensable portion of a well ordered canal, no one who has any practical acquaintance with inland navigation will attempt to deny. Where the reaches between locks are of considerable length the water surface is too extended to be materially affected by a single lockage, but where they are short it becomes necessary to make compensation for the want of area in the canal proper, by establishing outside basins on the same level, so that a single lockage shall not lower the water more than a few inches. If it falls as much as a foot, or more, vessels will be grounded, liable to injury, and to obstruct the navigation. In fact, a canal without basins is like a railway without sidings; it is not in a condition to do its work efficiently.

Mr. Page, in the 65th clause of his report, admits that "it is of course desirable to have basins adjoining reaches of moderate length, where they can be obtained at reasonable cost." And in the 53rd clause, speaking of his own line, he says:—*"There is only one reach without an outside basin, namely the one between the 23rd and 24th lock. The reach is, however, 780 feet in length, and nearly 160 feet wide at bottom—in fact it is a basin of itself."* Its value as a basin, however, will presently be shewn.

It must appear evident to any one who considers the subject dispassionately, that the question of basins was either overlooked or not properly appreciated by the Chief Engineer when he first set about preparing plans for the enlargement. The first plans exhibited to contractors at Ottawa related only to the upper portion of the loopline, and did not represent outside basins; the general specification referred to them only incidentally—they were not specified—but openings in the canal bank were provided for connection with them.

When the Board of Engineers met at Thorold they found there other plans, as yet unfinished, not exhibited at Ottawa, with outside basins drawn upon them, but still incomplete. The Board called for a return showing the area of each basin, including the canal surface. This was furnished by the resident Engineer. It showed still two reaches without basins, or rather two reaches without the requisite surface area, one having a basin of little value as such. Mr. Page admits of only one reach without a basin, but while his statement is literally correct, it is nevertheless a fact that on his line there are two reaches that will always prove an impediment to the proper working of the traffic. According to the return furnished to the Board, one of these had an area of 114,000, and the other an area of 177,800 superficial feet. The Board could not do otherwise than accept the return given, but it seems that Mr. Page has since varied the extent of the first by stating, in clause 53, that it is 780 feet long and 160 feet wide, equal to 124,800 superficial feet.

Then, as one of the locks of the enlarged canal of fourteen feet lift will require 172,800 cubic feet of water for a single lockage, the effect of taking a lock full of water out of this reach, which Mr. Page calls "a basin of itself," will be to lower the surface sixteen inches.

Navigators may not like the prospect of grounding their vessels upon a rock bottom, or of sticking upon the mitre-sills and so to assure them there is no danger of either, the Chief Engineer declares that such calculations as these "are worthless," because, with Lake Erie at his back, he can send down such a volume of water through the enlarged canal as will always keep it up to high-water mark, even when the locks are worked to their utmost capacity.

Here it is necessary at once to draw attention to the fact that Mr. Page suddenly changes front, and adopts a line of argument in defence of this basinless reach which, carried to its logical sequence, would prove all basins to be superfluous. If he can so readily dispense with one basin, he can just as well dispense with two, or three, or all of the basins which, on the other portions of the canal, he has gone to so great expense to construct. But because he cannot have a basin here, he, in the most illogical, and unwarrantable manner, assumes it to be unnecessary.

The fallacy of this argument must be apparent to any one practically acquainted with the working of the old canal. A prudent engineer should endeavour to economize the water by arranging his works so as to avoid waste, but here, from the outset, in order to compensate for defective construction, it is proposed in clause 59 to work the canal at high pressure, by wasting "a volume of water from three to six times greater than that required for lockage purposes."

In a previous report of the 27th February, 1872, to be found in the Public Works Report of 1878, the Chief Engineer, when putting to a test the calculations made by Mr. Brunel for supplying the canal by steam power from Lake Erie, showed that the quantity of water actually passing through the canal, was from nearly three to nearly seven times as much as had been theoretically assumed as necessary.

Balancing these two statements, one against the other, we are likely to find the enlarged canal, when opened, in the same unsatisfactory condition as the old one, in which, for years past, the want of water for the mills, and even at times for the navigation, has been such as to lead to seriously proposing to supply the canal by pumping from Lake Erie.

THE WELLAND RAILWAY

is a short line, 25 miles long, running from Port Colborne to Port Dalhousie, along the east side of the canal. It was built as a portage railway between the two lakes to lighten vessels passing through the Welland Canal. It is now leased to the Great Western Railway, and that part of it between Allanburgh and the Welland junction is at present used in connection with the Air Line. The new line of canal must necessarily cross this railway somewhere either north or south of Thorold. If it crosses to the north the drawbridge must be on the steep gradient of eighty-three feet in a mile. If to the south, the bridge will be on the level part of the line, which for the interest of the railway is to be preferred; but on this line the canal cannot be furnished with suitable basins, and hence the public interest is opposed to it. On the other hand, the proposed line through Thorold, which gives ample basins on every reach, leads to the northern crossing of the railway on its maximum gradient, and this crossing is objected to by Mr. Page, who states that a drawbridge in this position would render the railway "practically useless," and involve "the destruction of a great public highway." Evidently in his judgment such a crossing of the railway presents an insurmountable difficulty.

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Had the Chief Engineer been better acquainted with the practical working of railways he would scarcely have ventured an opinion so entirely at variance with its known results. Far more important railways on this continent are in successful operation, where the grades exceed that on the Welland Railway, and on which the trains must be prepared to come to a stand on any part of their line. The Boston and Albany has grades exceeding 85 feet in a mile. The Baltimore and Ohio, one of the most successful roads in America, climbs the Alleghany ridge from Piedmont at the rate of 116 feet in a mile for seventeen miles in succession, and the trains on this gradient are perfectly under control.

Moreover, it is a clearly defined principle in railway economy, where locomotive power is employed, that every company is bound, for the protection of life and property, to have sufficient break-power to control its trains on any of its grades. The chartered rights bestowed by Parliament upon the Welland Railway do not in any manner exempt that Company from the ordinary use of brakes, and it is believed that nothing more than the usual precautionary measures are necessary at this point, to render the crossing as safe as if it were on a level line.

It would undoubtedly be better and safer if draw-bridges for railways, and the crossings at grade of one railway by another, could be altogether avoided, and as traffic increases, it may yet be found expedient to substitute under or over crossings for many that are now in existence; but on a short line like the Welland, the great cost of such an alternative is not to be entertained. A crossing at grade may reasonably be resorted to, whether that grade is level or inclined; but because the best line for the canal, the best for the navigation, the best for the public interest, involves the crossing of this railway on its maximum gradient, and will put it to some inconvenience, the Chief Engineer prefers sacrificing the greater interest to the lesser. Although bound by his official position to see to the public interest, he takes the Welland Railway under his protection, and gives to Canada an imperfect canal.

The fact was pointed out by the Board of Engineers that the line through Thorold was the only line on which basins could be had on every reach, and they found no insuperable objection to establishing a drawbridge upon the gradient. It would doubtless be an inconvenience to the Railway, "but in view of the general interest of trade, it would be an inconvenience that must be submitted to as unavoidable." In the State of Massachusetts alone, according to official returns, there are no less than forty crossings at grade of one railway by another; but as a case in point, bearing upon the question under consideration, there is at Cedars Falls in Iowa a crossing of one railway by another, at grade, on an incline nearly the same as that on the Welland Railway, and where the conditions of stopping and starting trains have in like manner to be observed. There the Dubuque and Sioux City Railway crosses the Burlington, Cedar Rapids and Minnesota Railway on its grade of 78 feet in a mile, and yet the crossing on this grade has neither rendered the roads "practically useless," nor affected their "destruction as public highways." On the contrary, they are now in daily successful operation.

It must therefore appear perfectly evident, from the facts adduced, that the Chief Engineer has greatly exaggerated the difficulty of the crossing, that he has been betrayed into statements not borne out by the facts, and that the conclusions arrived at are erroneous and fraught with consequences most injurious to the best interest of the navigation.

In his futile attempt to extricate himself from an illogical position he does not confine his attention to the solution of the engineering problems under consideration.

but has gone out of his way to accuse the Board of Engineers of advocating "the destruction of a great public highway," "under the guise of a public improvement." While there is nothing in their report to warrant this gratuitous remark, the remark itself sufficiently indicates the animus which pervades the report of the Chief Engineer.

Being obliged, unexpectedly, to leave for England, my next letter will be written from thence.

BROCKVILLE, Aug. 8, 1874.

X.

On my arrival at Liverpool I spent two days in renewing my acquaintance with the extensive docks of this great seaport, which line the right bank of the Mersey for a distance of six miles along the front of the city, and enclose a multitude of ships of all sizes from every quarter of the globe. My attention was more particularly directed to the locks and docks of modern construction. In these I hoped to find examples bearing upon the important question of the most suitable lifts for the enlarged locks of the Welland Canal, referred to in my eighth letter; and in this I was not disappointed. Here are locks and dock entrances from fifty to eighty feet in width, furnished with gates of wood, and of iron, and of both materials combined, which according to the different stages of the tides are subject to pressure varying from fourteen to twenty-eight feet of head. In principle, too, these gates have to be quite as strong as those of any canal locks of the same width, having twice a day to bear the same hydrostatic pressure as that due to the constant head to which they would necessarily be exposed on a canal. Having been in use for upwards of twenty years they furnish a most complete and practical refutation of the extremely narrow views expressed by the Chief Engineer in clauses 68 to 88 of his report, to the effect that lifts exceeding twelve and fourteen feet are unsafe. On the contrary they prove the entire practicability of locks of even double these lifts, and shew that in point of fact the uniform lifts of sixteen feet suggested by the Board of Engineers for the enlarged canal, is a very moderate and safe recommendation,

THE TIME REQUIRED FOR PASSING A LOCK.

On the St. Lawrence Canals, where the locks are of the same width, but seventy feet shorter than the enlarged locks will be and where the chamber is filled through the gates only, the time generally occupied by a vessel in passing from one lock to another is from ten to fifteen minutes. Passing upwards last month in one of the large steamers, of 500 tons, I timed her through the Lachine and Beauharnois Canals and found it took from seven and a half to fifteen minutes to pass one of the lift locks. On the Erie Canal, according to official returns, boats of 200 tons have been passed through a single lock in four minutes, the average time for a whole day being nine minutes.

The probable time required for passing through one of the enlarged locks on the Welland Canal is not expressly stated in the Chief Engineer's report, but it may fairly be inferred from the following: In Clause ninety-two it is stated that means will be provided for filling the enlarged locks in three and a half minutes, but it is "not considered judicious to do it in less than about *five minutes*." And in clause sixty-one it is also stated "that the time occupied in filling a lock is not over *one-fourth* of that required for a vessel to pass from one level to another." According to these statements, therefore, the passage cannot safely be made in less than *twenty minutes*.

If we take into account the greater difficulty of handling vessels of one thousand tons, and the inadequate means provided for effecting the passage with reasonable de-

apach, it will be found when the enlarged canal is open that it will take from fifteen to twenty minutes to pass one of the locks—the latter being the safer estimate for this reason. The water being admitted into the chamber only in one direction, that is through the gate, it passes directly under the vessel's bottom, and along her keel to the lower gates, where piling up it lifted her stern and pitches her stern forward towards the upper gates, producing a heavy strain upon her snubbing line. If the strain exceeds the strength of the hawser she plunges into the gates, and there is an accident, with all its attendant damage and delay. To guard against this the sluices must be opened only partially at first until the lock is about half filled. Hence a longer time is required for the filling, as fully admitted in the report.

At Liverpool, where the gates are worked by hydraulic power, I found that notwithstanding their greater width, lifts, and general dimensions, they could be opened and closed in from three to five minutes, while at the entrance lock to the Victoria dock in London, which is eighty feet in width, the ponderous wrought iron gates are opened or closed in one minute by the same means—the whole time required for the passing of a vessel from a tide way depending of course upon the state of the wind and tide. I have seen sufficient, however, to enable me to state, with confidence, that had the suggestions of the Board of Engineers been adopted with such appliances for working the gates and sluices as modern engineering has produced, vessels could be passed through the enlarged locks in about *half the time* that the Chief Engineer considers necessary for that purpose. As it is my intention to refer to this subject again in my next letter, I now proceed to consider the other objections to

THE LINE THROUGH THOROLD,

to be found in clauses 40, 41, and 42 of the report.

Stated in plain language they are: 1. Damage to private property. 2. Crossing the principal street at an acute angle. 3. Increased curvature. 4. Crowding the traffic of the old and new lines in the first basin at Thorold, and 5. Drawing off the water for two winters. But in the usual exaggerated style adopted in the report one is startled to learn that "Forming a canal of the dimensions contemplated would, in twisting through the village of Thorold, dig the very heart out of the place." All these objections, however, are very weak and can easily be disposed of.

Damage to private property is unavoidable, and must be incurred on any line. It is measured simply by the amount that must be paid for it. It will not be necessary to purchase *five* mills but only *two*, and they are not of any great value—the rest can have their machinery changed to suit the new levels. The crossing of the main street can be shifted to the head or foot of the second lock without injury to the traffic of the village but with advantage to the working of the canal. The curvature, without being in anyway inconvenient, is really necessary in order to secure sufficient spaces between the locks and provide ample basins for the navigation. The crowding of the traffic is only a specious argument, and specious arguments can always be met and refuted. In this case, it is to be observed, that on the completion of the enlarged canal it will have a single channel one hundred feet wide at bottom throughout, it will be no wider above than below Thorold, and the track of vessels must be within this space. The volume of traffic both on the old and new lines, must be united either at or above Thorold, and move on in one channel above that village. It matters not where it is united or divided, so long as there is but one channel above and two channels below the point of divergence. But the idea of crowding is altogether imaginary. It cannot happen at Thorold, where the first basin is 1,200 feet long between the locks, and from 200

to 800 feet in width at surface, with two locks at each end, one for the larger and one for the smaller vessels, each keeping its own side of the canal. And lastly, in order to construct the enlarged locks on the line through Thorold there is no more necessity for drawing off the water in winter than there would be at Allanburg or at any point along the line of the canal where new works have to be constructed. If necessary it would be easy to point out the way in which the enlargement can be accomplished without recourse to such extreme measures.

TUNNELS THROUGH LOCK WALLS.

(Clauses 84 to 97 of Reports)

That it is quite practicable to fill and empty the chamber of a lock either through its gates or through its walls, there can be no doubt, as might easily be proved by reference to numerous examples. The former of these methods was uniformly adopted by me, in all the locks constructed in Canada after my plans up to the year 1852. In that year, however I was called upon by the Government to furnish plans for the Sault Ste. Marie Canal, and then proposed a longitudinal tunnel, or culvert through both walls, through which the lock was to be filled and emptied. If Parliament had then granted an appropriation there can be no doubt that the locks built after this plan would now be in successful operation. Since then, amongst other locks of the same class, one has been built in the Port of London, connecting the south dock of the the Surrey commercial docks with the Thames, in which a similar managment for filling the chamber through a culvert in the walls has been adopted. The same arrangement is found to answer a good purpose in the new combined locks on the Erie Canal at Lockport.

The advantages to be derived from the practical working of this plan are as follows : —1. The quicker passage of the vessel, by the facilities afforded of filling and emptying the lock, both through the walls and through the lock gates. 2. The safer passage of the vessel, and greater safety to the gates, by admitting the water in an even manner, as before stated, under and along its keel on both sides at the same time, so that surging is avoided, and the vessel rises on an even keel to the upper level. 3. There is no increase in the quantity of masonry, because it is disposed of in the most advantageous manner to resist pressure, but more security for a better class of it in the place where it is most required, while the mass of dead wall, is better placed to resist the impact of vessels. 4. The spreading out of the base gives greater stability to the wall, since its centre of gravity is thereby thrown more towards the back, and hence counterforts are unnecessary. In fact, where walls are high, and great masses of masonry necessary to retain the earth behind them, it is a more scientific way of employing it than the one adopted by the Chief Engineer, which consists in the assemblage of large masses of inert material at the base of the wall and in the counterforts.

It was but reasonable to suppose that a practical suggestion of this kind concerning the best interest of the navigation would be fairly and candidly considered. Such, however, was not the case.

In No. 89 it is stated that on the Ottawa canals, owing to the action of the water and frost, the tunnelled walls were injured to such an extent "that in order to save them from being entirely destroyed it became necessary to fill up the tunnels and introduce water through sluices placed in the gates." This statement is made without any qualification, as a sweeping condemnation of the plan, and then the general conclusion is drawn that "although tunnels, no doubt, answer well in some countries, they are nevertheless found to be quite objectionable where the action of the frost is so trying and severe as in Canada."

It is strange that any one occupying the responsible position of Chief Engineer should have allowed himself to make statements so entirely at variance with the facts. The Minister of Public Works, or any one taking an interest in the matter, could see any day in Ottawa, by looking at the combined locks at the entrances of the Rideau Canal, plainly visible from Dufferin Bridge, that these statements are incorrect. The tunnels of these locks are *not filled up*, and the locks are *not filled through the gates*, as stated, but on the contrary they are filled through the tunnels just as they were forty years ago.

It has been remarked that Dufferin Bridge in winter is the coldest place in Canada. If, then, as Mr. Page asserts, the severity of the frost was the reason for filling up the tunnels, how does it happen that these at Ottawa, which are more exposed than at any other place, are still open and in use? And if we refer to those mentioned on the Erie Canal, where the frost is quite as severe as at the Welland, what ground can there be for drawing the general conclusion that tunnels are inadmissible in our climate? The fact may now be stated, to which he has failed to refer, that on the Welland Canal the tunnels would not be liable to the action of frost, because, being always considerably under the surface of the water, they are not exposed to its influence as are the chain-holes, or passages made in the walls for the chains intended for working the gates. If frost was any objection to tunnels, much more would it be to the chain-holes which he himself has provided.

Again, in considering the question of tunnels, he does not confine himself to the simple idea of a culvert of masonry, as suggested by the Board of Engineers, but imports into it his own crude notions of wrought and cast-iron pipes, mixing up his views with theirs, as if they were in some way connected with their plan, and then states that it would involve an additional outlay of fifty thousand dollars at each lock, or one million of dollars for that purpose alone. No details of this estimate are given. It is to be taken entirely upon his own credibility. But that it is recklessly put forward to cover the defects of his own plans, must be apparent to any one practically acquainted with such matters if he considers that the statement amounts to this, that twenty-four locks can be constructed on his plan, for one million dollars less than the twenty locks proposed by the Board of Engineers; which is absurd.

In my next letter I intend to refer to the question of cost, and bring this series of letters to a close.

DOVER STREET, PICCADILLY,
LONDON, SEPTEMBER 22, 1874.

XI.

As promised in my last, I now proceed to examine

THE ESTIMATE

of the Chief Engineer, which he laid before the Public Works Department, in his report of the 12th March, 1878, in support of his own plans.

In looking through this report for the basis upon which it rests, it will be found in clause 97 that the tunnel system for the locks is charged with one million of dollars, and with regard to the other million referred to in the 108th clause, one is only left to conjecture that, as he reported that the line through Thorald would "*dig the very heart out of the place*," and also render the Welland Railway "*practically worthless*," the destruction of the village, and the purchase of the Railway are the two items to covered by this amount.

If this be so, and I can see no other foundation for it, then I must refer to my previous letter to dispel any apprehensions that might be entertained from the sensational notions advanced in regard to the two latter subjects; and will now proceed to consider the first mentioned, the tunnel system for the locks, along with the whole question of cost between the present plan, and that recommended by the Board of Engineers.

For the purpose of arriving at a fair comparison of the two plans, the special requirements of each may be distinguished in the following manner:—

I.—THE DEPARTMENTAL PLAN

Requires twenty-four locks of 12 and 14 feet lifts, but as the whole fall to be overcome between Thorold and Port Dalhousie is 320 feet the average of the lifts is 13½ feet. This plan requires more than necessary.

- (a) Four locks with four sets of lock gates and their machinery.
- (b) One pair guard gates.
- (c) Four waste-weirs with four channels for them around the locks.
- (d) The shifting of the line of the Welland Railway into deep side cutting.
- (e) Extensive retaining walls for the canal and water-courses, owing to the necessity of crowding into the narrow gorge the railway, the canal, and the artificial channel to be formed for the Ten Mile Creek.
- (f) Heavy cutting in rock and clay through the ridge dividing the Ten and Twelve Mile Creeks, instead of enlarging the old line.
- (g) The annual cost of four sets of lock attendants for day and night service for all time.

(h) The annual cost of repairing and maintaining four locks, four waste weirs and one pair of guard gates.

(i) And finally this plan involves loss of time, with increased cost of wear and tear for every vessel that passes through the canal hereafter, from the existence of four unnecessary locks, of 20 per cent. This is a very serious loss to which it is hardly possible to assign any money value, but the amount of all previous items can be approximately determined.

II. The plan suggested by the Board of Engineers requires twenty locks of the uniform lift of sixteen feet to overcome the same fall.

(k) For such uniform lifts the average increase in the height of the walls all round is 2½ feet, requiring an addition of about 1,200 cubic yards of masonry for each lock.

(l) The tunnel system for the locks, as before stated, does not increase the quantity of masonry, because it is disposed of more advantageously; but it requires a better class of it in the lower part of the work. The quantity affected by the change is about 1,167 cubic yards in each lock, the value of which is about fifty per cent. more than the other masonry.

(m) Four additional wicket gates to each lock for the tunnels.

(n) The purchase of two mills in Thorold, and the alteration of the machinery of three more to suit the new levels, changing part of the line of the main street so as to have the swing bridge at the foot of the second lock; also, purchase of village lots, and damage to property on the line diverted.

III. Difference of cost for locks.

According to the prices at which the contracts for the new works on the Welland Canal have been let, the average cost of a lock on the present plan, including masonry, foundations, excavation, filling about walls, lock gates and machinery, waste weirs, sluices, and channels around locks, will be about.....

	\$123,000
The probable cost of the re-arrangement of the locks for uniform lifts (k) will be, each lock.....	14,400
The probable increased cost of masonry for the tunnel system (l) will be each lock.....	7,000
The cost of additional wickets (m) each lock.....	1,000

Probable cost of lock, w. weir, &c., on plan suggested..... \$145,400

These elements afford the means of arriving at a fair approximation to the real difference of cost between the two rival plans.

The official plan requires 24 locks, waste weirs, &c., at an average cost, as above stated, of \$123,000..... \$2,952,000

The plan suggested by the Board of Engineers requires only 20 locks, waste weirs, &c., at an average cost of \$145,400 each..... 2,908,000

Difference in favor of the latter	\$44,000
Add to this the cost of a pair of Guard Gates at Thorold (b).....	50,000
Add charging the line of the Welland Railway (d)	25,000
Add retaining walls for canal, and artificial channel for Ten Mile Creek (e)	84,000
Add the difference of cost between enlarging the old canal above Thorold and making an entirely new canal through the ridge dividing the Ten and Twelve Mile Creeks (f).....	104,000
Add the capitalization, at six per cent., of the annual cost \$4,820, of the attendants to the four unnecessary locks (g).....	72,000
Add the capitalization, at six per cent., of the annual cost of the repairs, estimated at \$1,200 for the four locks, the four waste weirs, and the guard gates (h).....	20,000
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	\$349,000
Deduct from this the purchase and alteration of the mills, diversion of of part of Main street, purchase and damage to property in excess of new line (n).....	90,000
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	Saving by plan suggested \$259,000

beside the loss of time, &c., referred to in item (i). The items (d), (e), and (f) can be definitely ascertained by reference to the sections in the canal office, but it is believed that the sums entered for them represent their cost with sufficient accuracy for the present purpose.

It is unnecessary to take into account the cost of forming the canal and basins between the locks, because there would really be little or no difference on either line. By the exercise of the best engineering skill in the location of the locks, and basins on the suggested line, the quantity of earthwork would be reduced to a minimum, and that minimum would not exceed the quantity called for by the present plans, especially when we consider that as four basins would be saved by the enlargement of all the basins, the banks dividing these basins would be saved. Therefore, in assuming the costs of the excavation to be the same on both lines, I cannot be accused of unduly favouring the changes recommended by the Board of Engineers.

Then, as regards the relative cost of the locks, it is to be observed that the estimate produces the result that might reasonably have been expected. The twenty locks of sixteen feet uniform lift cost nearly as much as the twenty-four locks of twelve and fourteen feet lifts, the difference being about one and a half per cent. in favour of the former. This is mainly owing to the fact, readily understood by practical engineers, that heavier walls are required for greater lifts, so that although it is quite true, as stated in my eighth letter, that the four locks saved would cost upwards of half a million of dollars, yet when the cost of twenty is balanced against twenty-four locks for overcoming the same fall, the result proves the statement of the Board of Engineers to be quite correct, that there is really no material difference in the cost of the two plans.

Thus after a careful and impartial examination of the estimate, it is proved that instead of the suggested changes involving an additional outlay of two millions of dollars as stated by Mr. Page, or nearly *forty per cent.* on the cost of the new line, there would really be a saving of upwards of a quarter of a million, or about *five per cent.*, by following the better plan.

The total cost of the new line, as given in the general report of the 29th April, 1872, is \$5,180,000. In the interest of the public it is to be hoped that this estimate, given in bulk sum, will bear investigation better than the one I have just been dealing with.

In summing up, at end of his report of the 12th March, 1873, the Chief Engineer, in the 108th clause, emphatically states that "no advantage would be gained by adopting any of the suggestions of the 'Engineers,' but on the contrary there is good reason to believe that if they were followed a less efficient canal would be constructed, and that, too, at an additional cost of two millions of dollars."

On the other hand, the Board of Engineers reported, in substance, that the changes which they suggested would afford greater facilities to the navigation, and that they could be effected without any material difference in cost from the official plans.

Here then, two distinct and totally opposite opinions were submitted for the consideration of the Department. The questions at issue were of vast importance, and the decision to be arrived at involved very grave responsibility, but owing to the unusual course adopted by their responsible advisers in refusing a conference with the Board of Engineers, the Department took action without having the benefit of such full explanations and criticisms as I and my colleagues could offer; consequently with out being sufficiently informed on the subject.

Those of my readers who have followed me through my previous letters on this subject will now understand why I deplore as fatal to the best interest of the country the determination of the Department to carry out the official plans with all their imperfections, and how much it is to be regretted that the present Government does not interfere to avert the injury.

The public should carefully weigh the import of this decision, as it involves certain heretical principles in engineering which are thereby avowedly to be carried out in our Public Works, not only on the Welland, but on the St. Lawrence Canals, and which must materially affect their utility.

Since Mr. Page's plans have been adopted, without modification, the conclusion inevitably follows that the Public Works Department sees *no advantage* in having ample basins on every reach for the proper working of the traffic; *no advantage* in having all the locks of the same uniform lift throughout; *no advantage* in the saving of four locks, and the other works and expenses connected with them; *no advantage* in the adoption of such a modification of the official plan as will have the effect of practically doubling the capacity of the canal by reducing the time of passing the locks one-half; and not only that the Department sees *no advantage* from such beneficial changes as were suggested, but that in supporting their responsible officer, they accept without question, and adopt without proof, an estimate which is entirely fictitious.

Before bringing to a close my remarks on the official plans for the enlargement of the Welland Canal, it is necessary to direct attention to one other defect, being one of the "minor points" referred to, but not specially mentioned in the report of the Board of Engineers. It is the vertical slope given to the face walls of the lock. With the exception of the recesses for the gates, which are plumb, the same slope is given to the chamber as to the entrances at either end, and all the face walls are in the same plane. The slope is such that a lock of fourteen feet lift is twenty-nine inches wider at the top than at the base of the walls, and uniformly the same both at the quoins and in the chamber; so that there is nothing to prevent a vessel exceeding the standard width of forty-five feet adopted for the navigation (or two vessels if locked through at the same time), entering the lock and getting crushed between the wall, when the water is drawn out. This is no imaginary danger. The occurrence of such an accident some years since in the port of London from a similar condition of the lock walls, induced the Engineer of the Millwall lock to make all the face walls of that lock vertical. On the St. Lawrence Canals, where the chamber walls were sloped, this danger is obviated by having a small portion of the face wall at the gates made vertical, so that no vessel exceeding the standard width can be admitted into them.

I have now completed my task, and have endeavoured throughout the discussion to confine my attention strictly to the engineering questions before me, and to treat them in a professional, not personal manner: not offering mere opinions, but adducing facts and arguments, leaving it to my readers to judge whether or not I am thereby justified in the conclusions arrived at.

Yours truly,

SAMUEL KEEFER,

St. LEONARDS-ON-SEA, NOV. 4, 1874.

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